# Progress Report

## RESPONSE OF TENSION PILES TO VERTICAL SEISMIC MOTION IN SATURATED FINE SAND

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### Progress to Date

Because of administrative delays, actual work did not commence on the project until August 1, 1988. The major emphasis during the next six months, the period covered by this report, was on developing the hardware and software to conduct the unique set of tests that have been proposed. Considerable headway has been made during this period, as documented below; however, the testing system is not yet in operating order, and no "production" tests have yet been conducted. Therefore, no test results or their interpretations can be reported.

During the first six months of the project the following operations were accomplished:

Literature Review: The review of the literature that was made for the preparation of the proposal has been expanded. Empahsis has been placed on papers addressing the scaling of earthquakes and the cyclic response of piles in granular soils. Based on information that has been acquired recently, it appears that it would be advisable to make initial soil density a variable in the test process. This will require modification of the testing schedule described in the proposal.

Selection of Object Seismic Event: Complete, three-degree-of-freedom, acceleration time histories were obtained from Sandia Laboratories for the SIMS seafloor accelerometer package for the Palm Springs and Oceanside events of July, 1986 ($M = 6 \pm$, with distance from the causative faults of about 125 and 75 km, respectively). Both records exhibited extremely low peak accelerations, especially in the vertical mode, and initial rough computations indicated that no degradation of piles would likely have occurred at the SIMS site due to these events. It was therefore decided to scale the records. After considering several scaling techniques, it was decided to use the technique of Trifunac to scale the records in the frequency domain and map the resulting functions back into the time domain for purposes of controlling the testing equipment. Scaling was done assuming that the relative position of the causitive fault and the SIMS location remained invariant, but that the Richter magnitude of the seismic event increased to 8.0. In order to control the Instron testing machine through the resident controller, which is displacement based, the scaled acceleration records were then transformed into displacement time histories. Upon examination of these time histories, it was decided to use the vertical and predominant horizontal modes from the Ocenaside event in the tests in this program. These scaled records are now in place on the hard disk of the control computer.

<u>Assembly of the Testing Apparatus</u>: The testing apparatus has been fully constructed during the first six months of the project. This apparatus includes a pressure chamber, as shown schematically in Fig. 3 of the proposal. The only significant deviation from the chamber that was originally planned is the elimination of an accelerometer to be buried in the soil. This elimination is required by the fact that the scaled accelerations are so small that a very massive accelerometer would be required, which would potentially set up its own response with the soil, such that it would not actually sense free-field soil accelerations. Instead, it was decided to control displacements at the base of the chamber through an LVDT, assuming that the chamber base and the soil at that level move in phase and that such motion is representative of the soil motion measured by the SIMS unit.

The reduced, scaled earthquake records require an excursion in the vertical mode of approximately four inches during a simulated earthquake, which is much larger than we had expected. In order to fit the test chamber into the Instron testing machine and still accommodate this excursion, it was necessary to reduce the height of the chamber to 23 inches instead of the 28 inches that was planned. The planned diameter of 20 inches was maintained.

The chamber has been filled and pressurized several times with total pressure transducers in place to measure normal pressures in the sand and their relation to indicated pressures in the pressurizing membrane. It was found that the "membrane effect" is very small with the system that was constructed (applied air pressures are within 10% of total pressures measured in the sand in the chamber); nonetheless, correction terms for membrane stretching have been developed and will the applied during the production tests.

The biased loading assembly has also been constructed and tested. This assembly consists of a shieve positioned directly over the test pile through which is passed a flexible airplane cable, which is attached to the top of the pile and exerts a vertical pull. The cable then passes through another shieve, at the same approximate elevation as the shieve above the pile, located on a fixed loading frame positioned four feet from the test chamber mounted in the testing machine. A dead-weight hanger is attached to the end of the cable that passes through the shieve in the fixed loading frame. This hanger consists of a small vessel into which is placed small-diameter lead shot that establishes the magnitude of bias tension load on the pile. At present the shieve that is positioned directly over the pile is stationary, which is adequate for vertical shaking tests (as proposed).

Once the simulated earthquake loading portion of the test is completed, more measured lead shot is added to produce uplift failure (if such does not occur during the simulated seismic event) without first unloading the pile. Just above the hanger is placed a spring of low stiffness to prevent the static load from vibrating with the pile, thus keeping a near-constant biased tension load on the pile during shaking.

[It is quite straightforward to replace the shieve directly above the pile with a shieve on a rotating arm, reposition the pile to enter the chamber through a port offset from the centerline, and excite the chamber through torsion to approximate horizontal motion. Although horizontal loading was not oiginally proposed, we would like to carry out such tests later to investigate whether horizontal ground motion is more or less destructive to a pile loaded in biased tension than is vertical ground motion.]

<u>Design and Construction of Raining/Saturation Apparatus</u>: Sand placement will be by air pluviation, and an appropriate pluviatile compactor (rainer) has been constructed and tested. Techniques have been developed, based on the rate of placement of the sand, to obtain consistent relative densities of about 55% and 85% in the San Jacinto River Sand.

These will now be the initial relative densities employed in the tests. In order to place the miniature pore water pressure transducers under water (to maintain saturation), continuous air pluviation will be followed by continuous gravity saturation with deaired water from the bottom up, so the the free water level is maintained just below the present surface of the sand. At the time of this writing, several trial fillings of the chamber have been made to assess reproducability of the compaction process.

Construction and Calibration of Pile and Instrumentation: A segmented test pile with three levels of strain gages mounted internally has been constructed, instrumented and calibrated. The pile can be assembled to be either 17 inches or 10 inches in length. A manually operated pile driving hammer and cushioning system has also been constructed. The test pile has been driven into the filled and pressurized chamber several times with this hammer/cushion system to ensure that the pile can be driven at a penetration resistance that is representative of field values without overstressing the pile or damaging its instrumentation.

The soil-mounted pore water pressure transducers and the LVDT's to be attached to the chamber and to the pile have also been checked and calibrated in the UH laboratories.

Data Acquisition System: The data acquisition system, as described in our proposal, is one that has been used in tact on other projects. We have checked it out and have found it to be operating properly.

Control Software: It has been necessary for us to develop all of our own software to control the testing machine during the simulated seismic events. This software will reside in a microcomputer adjacent to the testing machine. We have experienced some delays in developing this software because the Instrōn Corporation (manufacturers of our testing mahine) provide only Hewlett-Packard subroutines, while our contol computer is an IBM, MS-DOS-type machine. Within the last few days, we have been able to acquire IBM software and believe that we can complete the development and checkout of the necessary control programs during February. This remains the only major problem to be solved prior to beginning "production" testing.

Operations Proposed for February - April:

During February the following operations are planned:

(a) appropriate baseline static uplift tests will be performed,

(b) the control software will be completed and checked,

(c) a final decision will be made relative to a revised testing schedule to include two values of relative density of the soil.

During early March we plan to conduct a sufficient number of shaking tests to verify the operation of the system. By mid-March, we hope to be performing production tests, which we presently expect to require about 10 weeks to complete. During each production test, we plan to develop the following data, which will be reduced and interpreted in detail later:

(a) displacement time history at the base of the chamber (to be compared to the programmed displacement time history),

(b) time history of displacement of bias-loaded pile relative to the bottom of the chamber,

(c) pore water pressure time history in the "near field" (transducer nearest the face of the pile),

(d) pore water pressure time history in the "far field" (transducer most distant from the face of the pile),

(e) force time histories at the pile head, pile toe, and middepth of the pile (the latter only for the larger penetration when all three segments of the pile are mated together). We suspect that degradation may begin near the toe of the pile and progress upwards during a seismic event. Therefore, time histories of differences in indicated loads at the head, middepth and toe may also be studied and plotted against time, if definitive.

As the testing program progresses, we would like to demonstrate the apparatus and discuss the test results with our sponsors in our laboratory. We will be trying to arrange a meeting at UH as soon as the testing system is operating smoothly and we begin to see emerging patterns in the test results.

Budget Considerations

We do not forsee any problem completing Phase I of the project within the budget that has been allocated for the project.

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